Can Double Auctions Control Monopoly and Monopsony Power in Emissions Trading Markets?

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Abstract

We conduct a laboratory experiment to investigate whether the double auction institution can suppress market power in emissions trading markets. We study twenty-four markets with varying market structure in a ABA crossover design which controls for subject effects. We find clear evidence of successful use of market power. Average prices rise under monopoly and fall under monopsony. Opening prices are affected much more than closing prices. Profits are redistributed in favour of the agent with power. Efficiency is not affected significantly. Analysis of convergence trends suggests this is not a transitory phenomenon. We interpret our results as evidence of successful price discrimination within a double auction market.

Key Words: Emissions trading, double auctions, market power, tradable permits, price discrimination

JEL Categories: Q28, C91, D42

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1. INTRODUCTION

Emissions trading is frequently advocated as an institution for market-based environmental regulation, however practical implementations were rare and unique to the United States until the 1990's.[2] Since then the success of American initiatives, in particular the U.S. EPA SO_2 emission permit market , have increased international enthusiasm for this institution . It may be optimistic, though, to expect that American successes will be easily replicated elsewhere. The SO_2 market has been characterized by large numbers of sellers and buyers and trading has taken place using transparent institutions. These features have been important in generating the competitive market outcomes and benefits which the approach promises. Application of the institution in other countries or in an international arena may, however, involve markets with less-competitive characteristics. In particular, they could be sufficiently dominated by large sellers or buyers to create market power. At the international level, it is frequently thought that the United States will be a dominant buyer and the states of the former Soviet Union dominant suppliers in Annex I trading under the Kyoto protocol. Nordhaus and Boyer [17, p.121] estimate that the United States will account for approximately 44 percent of carbon emissions permit purchases by 2010 while the former Soviet Union will account for nearly 56 percent of sales. By 2050 the share for the United States will fall to 39 percent while the share for the former Soviet Union will rise to 68 percent (in both 2010 and 2050 eastern Europe will account for the balance of sales). These estimates are based on competitive market pricing. Bernstein *et al.* [1, p. 250] estimate that full exploitation of monopoly power by Eastern Europe

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[1] The funding for the laboratory sessions described in this paper was provided by a McMaster University Arts Research Board grant to Muller. The paper has benefited from comments by Tim Cason, Dan Friedman, Rob Moir, seminar participants at a number of universities and several anonymous referees.

[2] Emission permit markets were first discussed by Crocker [4] and Dales [5].

and the former Soviet Union could induce a monopoly mark-up of 180 percent and raise international carbon permit prices from US$90/tonne to $129 per tonne.

These concentration concerns are particularly relevant if trading under the Kyoto Protocol is implemented on a country-to-country basis. If countries delegate trading authority to polluting firms, concentration in world greenhouse gas markets could be significantly lessened. High market concentration may still be a problem in trading permits for other pollutants, however, particularly in markets for regionally restricted air and water pollutants. For example, the Ontario Ministry of Environment [22] has announced a mandatory cap on nitrogen oxide (NO_x) and sulphur oxide (SO_x) emissions from six fossil fuel generating stations in the beginning of 2001. The generating stations are all owned by Ontario Power Generation (OPG), but these may be sold in the future. Current production of NO_x is about 50 kilotonnes (kt) per year, well in excess of the cap of 36 kt. The shortfall can be made up by purchases of emission reduction credits from sources in the non-capped sector. The market for these credits is geographically restricted by a requirement that they be generated by sources in or (to a limited extent) upwind from Ontario. Specific measures are proposed for discounting credits generated more than 300 km upwind of the region. OPG has undertaken an extensive program of amassing and banking these credits. There are no other purchasers. Off-the-record comments from industry observers suggest that OPG is paying distinctly less for these credits than might be expected in the United States. This is consistent with the exercise of monopsony power.

The effective exercise of market power in emissions trading markets might raise concern on two distinct grounds. First, of course, market power may restrict the net sales of permits and lead to an inefficient allocation of responsibilities for abatement. Secondly, market power may redistribute the gains from trade in a direction that may or may not be viewed favourably, depending on one’s political perspective. Note that it is possible to have the second effect without the first if the traders with market power are able to practice price discrimination. Porter [20] has conjectured this is a possibility in double-auction markets.

Referring to laboratory evidence, Bohm [2, p. 55] has suggested that potential market power in emissions trading may be controlled by using double auctions.[3] The relevant laboratory evidence consists of papers by Smith [22], Smith and Williams[23], Ledyard and Szakaly-Moore [13], Brown-Kruse *et al.* [3], and Godby [7, 8, 9]. In fact, this work provides only mixed support for relying on double auctions to control market power. First, only Ledyard and Szakaly-Moore [13] and Godby [7, 8, 9] capture an important aspect of field markets for emissions permits, namely that participants may act as traders (alternatively buying or selling permits according to changes in cost conditions and price levels). The remaining studies designate some traders as buyers and some as sellers. The trading environment may differ from the buyer and seller environment because in the former potential sellers of emissions permits generally have the option of earning profits by using unsold permits in their own operations. This opportunity may make sellers less vulnerable to counter-withholding by buyers. Moreover, trading environments allows speculation and consequently may introduce more noise into prices. In fact the laboratory studies with trading seem to detect more successful exploitation of market power than the studies with buyers and sellers.

Second, even the seminal work by Smith [22], which shows that the double auction can largely control deviations from competitive prices, detects evidence of output restrictions under monopoly conditions. Third, Brown-Kruse *et al*. [3] and Godby [7, 8, 9], in the two studies which examine both monopoly and monopsony power, provide some suggestion that *monopsonists* have more success than

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[3] A double auction is organized like most stock markets. Any agent may submit a bid to buy, an offer to sell, or an acceptance of an outstanding bid or offer. Outstanding bids, offers, and transactions prices are common knowledge. After summarizing laboratory work in this area written prior to 1996, Holt [12 , p. 398] concluded that "sellers are sometimes able to exercise market power in double auctions, but the influence of seller market power is much weaker (in the double auction) because of the incentives to offer last-minute price concessions and the more active role that buyers have in this institution."

monopolists in exploiting power in laboratory markets.[4] Because the theories of monopoly and monopsony are symmetric, this asymmetric result is surprising.

In addition to the mixed support shown for the control of market power by the double-auction pricing institution, these studies suffer from some important methodological drawbacks. They all have a small number of market power sessions.[5] They use between-subject rather than with-in subject designs, which would have greater statistical power. Finally, they do not provide a direct comparison of competition with market power under identical conditions of supply and demand.

In short, the limited laboratory evidence suggests that it is premature to be sanguine about the ability of double auctions to control market power in emissions trading markets. The suggestion that monopsony power may pose a greater threat than monopoly power is particularly disturbing because, as we have seen there is a real possibility of high concentration on the buying side of many emerging emissions trading markets. It is important to discover if this asymmetry in performance reappears in related laboratory environments. Moreover, given the many contexts in which concentrated emissions markets may arise, it is important to confirm that market power actually does emerge in well controlled laboratory environments.

In this paper we present a laboratory experiment which permits a controlled contrast of competition with monopsony and monopoly power in a double auction market with common cost parameters. The statistical power of the contrast is enhanced by a within-subject design and a larger number of markets than in previous studies. We capture the emission trading environment by letting our subjects act as traders

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[4] Despite high prices in earlier periods, by the last period final transaction prices in two of Godby's monopoly markets were below competitive levels. It was not clear whether this was a transitory phenomenon or an indication that these markets were beginning to converge to a competitive price after several periods of high prices.

[5] Smith [22] runs three monopoly markets, Smith and Williams [23] run five, and Ledyard and Szakaly-Moore [13] run three. Brown-Kruse *et al*. [3] and Godby [7, 8, 9] each run three monopoly and three monopsony markets.

rather than designating them as buyers and sellers, and by ensuring that the emission permits have value to the traders even if they do not trade their permits. The results of the experiment suggest that both monopolists and monopsonists can cause average prices to diverge from competitive levels and shift the trading surplus in their favour. However, efficiency is not significantly reduced from competitive levels. Monopolists and monopsonists have comparable success in appropriating surplus.

2. EXPERIMENTAL DESIGN

We created a market environment in which ten subjects traded ration coupons in a computerized double auction. Subjects were informed that they each represented a firm which produced a product from several inputs.[6] Each period the firm received revenues from selling its product and incurred costs from purchasing inputs. One input, called *leets*, was rationed and could only be obtained by surrendering a ration coupon. No additional payment was required. Using leets increased profits by reducing other operating costs. Thus the marginal value of a ration coupon was equal to the increase in total operating profit induced by employing one more unit of leets. Coupons were distributed at the beginning of each period to some subjects but not to others. Subjects receiving coupons could use them to increase operating profits or sell them to other subjects. Subjects who did not receive coupons could choose to buy them. Once bought, these coupons could be used to increase operating profits or resold to other subjects. Thus all subjects were allowed both to buy and sell coupons, but no short sales were permitted. Coupons could not be carried over to future periods.

Clearly, the use of leets is analogous to the use of the environment to assimilate emissions and ration coupons are analogous to annual emission permits. We adopted the leets/coupons terminology in order to prevent the subjects' being influenced by emotional reactions to the concept of emissions trading and to be consistent with the terms used in the software.

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[6] Visit *www.socsci.mcmaster.ca/~econ/mceel/abstracts/etmp-instr.htm* for the complete instructions.

Subjects traded coupons in a computerized double auction market.[7] They were guided in their trading by a *wizard*, a small window on their computer screens which informed them how much adding or subtracting one coupon from their holdings would change their operating profits. A market consisted of a number of trading periods. At the end of each trading period, subjects were informed of the redemption value of their coupon holdings, their net sales revenue and their operating profit for the period. Total earnings, including profits from trading, were continuously displayed in an inventory screen. Cumulative earnings for the market were displayed after the last period in each market.

Each experimental session contained four markets: one practice market lasting two or three periods of 10 minutes each and three regular markets lasting for 10 periods of three minutes each. During the unpaid practice market subjects were carefully instructed in the use of the software. Following this, subjects participated in the three "real" markets for that session. Subjects recorded their earnings at the end of each regular market. At the end of the session they were paid their earnings privately in cash.

The redemption values used in the experiment are derived from those used by Smith [22], Smith and Williams [23] and Ledyard and Szakaly-Moore [13]. The original parameters were expressed as supply and demand schedules. They induced a single competitive equilibrium price, an efficient trading quantity of eight, and a market power equilibrium quantity of five. We made four adjustments. First, we eliminated the need for commissions by raising the demand curve and lowering the supply curve to create an equilibrium price tunnel of five cents.[8] Secondly, we altered the supply curve to maintain the three unit separation of the competitive and market power predictions. Thirdly we expressed the sellers' marginal

[7] We used the RNSC double auction reported in Godby, Mestelman, Muller and Welland [10] and described in more detail in Mestelman and Muller [15].

[8] A referee notes that trading commissions (as used by Smith) may create a greater incentive to undertake marginal trades than our equilibrium price tunnel does. If this is so, Smith's results will be biased towards obtaining competitive outputs.

opportunity costs as redemption values. Finally, we introduced fixed costs and revenues computed so as to induce a profit of 100 cents per period for each player when coupons are efficiently allocated and the market price is at the mid-point of the equilibrium price tunnel (87 cents). These baseline parameters are reported in Table I and are reflected in the supply and demand schedules shown in Figure 1.

We considered three market structures: competition, monopoly and monopsony. In the baseline (competitive) environment, each agent received two redemption values. The five agents who were expected to be net sellers each received two coupons per period. The remaining agents received no coupons. Note that the distinction between buyers and sellers depends entirely on equilibrium prices. In actual fact all participants were traders, who were permitted both to buy and sell and to speculate if they chose.

In the monopoly environment we combined the redemption values of the agents who had received coupon endowments into a single schedule, which was assigned to a single subject. The remaining four agents were shut out of the experiment. They remained at their terminals during the market power portion of the experiment, but they were not permitted to make trades. They were invited to observe the trading or to read a book. Their attention was drawn to the experiment, however, because they were required to respond to computer prompts at the beginning and end of each period. The locked-out traders received fixed revenues sufficient to yield profits of 100 cents per period.[9] Similarly, the fixed costs of the monopolist were raised to yield an expected profit of 100 cents at the efficient allocation. The monopsony treatment was like the monopoly treatment, except that we combined the schedules of the subjects expected to be net buyers. The monopoly and monopsony parameters are reported in Table I and are reflected diagrammatically in Figure 1.

As noted, each of the sessions consisted of a practice market and three “real” markets (denoted

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[9] The market power environments are consistent with a single firm in a five-firm industry acquiring the fixed costs of the remaining firms and assuming control over all industry output and price decisions in return for guaranteeing to the other firms payments equal to the competitive profits they have forgone.

Markets 1, 2 and 3 in this paper). Markets 1 and 3 always had the same market structure, which contrasted with the structure used in Market 2. Monopoly and monopsony market structures were independently contrasted with competition in two ABA crossover designs (see Table II). Different redemption values were used in each market. The redemption values in the practice market bore no relationship to the values in the real markets. The basic parameter sets of Table I were used in Market 1. In Market 2 all redemption values were displaced downwards by subtracting 23 cents from each coupon value. In Market 3, all redemption values were displaced upwards by 26 cents from the baseline values. Fixed revenues were adjusted to maintain a profit of 100 cents for each agent under an efficient allocation.

3. BENCHMARKS AND PREDICTIONS

We computed trading volumes, prices, profits and gains from trade under four benchmark predictions (Table III). The no-trade benchmark represents the result of the initial distribution of coupons. Buyers earn 244 cents per period and sellers earn 305 cents, for a total of 549. Gains from trade are the increase in profits from these benchmarks. The competitive (or efficient) benchmark is the configuration which maximizes the total gains from trade. With this allocation, eight units are traded at a price between 85 and 89 cents and buyers and sellers both earn 500 cents per period, a gain of 256 cents for buyers and 195 cents for sellers. Total profits rise to 1000 cents, thus the total gains from trade are 451 cents.

The monopoly and monopsony benchmarks are the configurations which would maximize the gains for a single seller or a single buyer posting a single price. The monopolist would post a price of 113 cents per unit, the monopsonist 61 cents. Under the benchmark monopoly and monopsony allocations, five coupons would be sold. Note that the benchmarks are not predictions of outcomes in our laboratory environment because our single agents were not restricted to a single price in each period. This allows the emergence of price discrimination. Moreover, in our environment there is a distinction between net trades and total transactions, because some traders may have both bought and sold coupons. Consequently the total quantity traded may exceed the benchmark for coupons sold, which refers only to net trades.

Under the monopoly benchmark, sellers collectively would earn 601 cents, of which 400 would be fixed revenue payments to the inactive sellers and 201 would be the profit of the monopolist. Buyers collectively would earn 344 cents per period. Gains from trade are 296 cents for the single seller and 100 cents for the buyers collectively. Total gains from trade are 396 cents, or 87.8 percent of the total possible gains of 451. Under the monopsony benchmark buyers collectively would earn 604 cents, of which 400 cents accrue to the inactive participants and 204 would be the profit of the monopsonist. The sellers collectively earn 341 cents. Gains from trade are 360 cents for the single buyer and 36 cents for the sellers collectively. Overall efficiency is 87.8 percent, the same as in monopoly. The benchmark prices and quantities are displayed in Figure 1.

4. RESULTS

We conducted eight sessions. The eight subjects who were to be given the role of monopolist or monopsonist were recruited from post-doctoral fellows and graduate students in Economics and Business.[10] The remaining seventy-two subjects were recruited from the general student population through advertisements and classroom announcements. Sessions were planned to last for no more than 3 hours. Due to computer failures in a number of runs, the sessions lasted somewhat longer, up to 3½ hours. On these occasions, subjects gained additional trading experience in the aborted sessions. Due to the length of the sessions, three subjects had to be excused (one in one session and two in another) . These were replaced by available graduate students (one in Mathematics and one in Economics), who had participated in a pilot

[10] We chose our market power subjects from a special subject pool because we wished to give market power the fullest chance of emerging. These subjects were informed that in some portions of the session they would have market power, but they were not instructed on how to use it nor were they informed of the specific market in which they would have market power. Smith (p. 86) used graduate or advanced undergraduate student as subjects and preselected monopolists who were thought "not likely to be easy on the buyers." Smith and Williams (p. 36) followed a similar selection process, chosing monopolists based on "experience in several previous experiments and exhibiting a pattern of 'toughness' in pursuing their self-interest." Using an *ex post* classification, Ledyard and Szakaly-Moore found a significant difference between strong and weak monopolists in their emissions trading markets.

session the previous week. In one case a competitive market was terminated after 8 periods because of time constraints. After each session was over subjects completed a debriefing questionnaire and were paid privately in cash. The competitive subjects earned between $11.82 and $36.23 (mean $26.22) for their participation, plus a $5.00 show-up fee. The subjects with market power earned $39.13 to $66.91 (mean $48.16).

4.1. Average Prices

Due to the presence of some outlying observations, the average behaviour of prices in each period is better captured by median prices than by means.[11] Table IV summarizes the means of these median prices, computed across all ten periods of each market and cross tabulated by market structure. For comparability with Market 1, prices in Markets 2 and 3 have been normalized by adding or subtracting the relevant shift parameter.

Table IV reveals a clear effect of market structure on average prices. The mean normalized price over all competitive sessions (85.61 cents) is within the competitive equilibrium band of 85 to 89 cents. The mean monopoly price (98.89 cents) is much above the competitive band but distinctly below the benchmark monopoly price of 113 cents. The mean monopsony price (65.95 cents) is somewhat above the benchmark of 61 cents. Mean prices in the second market were somewhat above mean prices in Markets 1 and 3. Averaged across all three markets mean monopoly prices are 13.18 cents higher than mean competitive prices and mean monopsony prices are 19.66 cents lower.

These differences are overwhelmingly statistically significant. A simple two-way analysis of variance on treatment and market retains the null hypothesis of no market sequence effects ($p = 0.2516$) and strongly rejects the hypothesis of no treatment effects ($p = 0.0000$) This result might be challenged on two

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[11] Because we wished to permit speculation, we did not prevent traders from making apparently unprofitable trades. Occasionally a trader will omit a digit or type an extra digit while entering data. These erroneous bids or asks, which would seriously distort arithmetic means, may be accepted before they can be corrected.

grounds: first because the panel nature of our data implies that the observations in any one session cannot be assumed to be independent and second that computing the mean across markets discards information in the period-by-period data. Table V reports a number of more sophisticated regression models which confirm the significant influence of market structure on median prices. In that table, Model 1 is the regression underlying the ANOVA model of Table IV, estimated using a robust estimator to allow for autocorrelated or heteroscedastic disturbances.[12] Both market structure dummies are highly significant and the joint hypothesis of no structure effect is rejected at the 0.001 level. Model 2 reports the same regression model based on the mean of median prices for the last seven periods of each market. This formulation discards data from the first three periods on the grounds they are transitory adjustments to new parameter sets. Compared to Model 1, the fit of Model 2 is distinctly improved. The market order dummies are individually and jointly insignificant. The estimated main effect of monopoly and monopsony are almost unchanged at 12.49 cents and -20.30 cents respectively.

While striking, the previous results do not exploit data from individual periods of each session. Doing so could provide more precise estimates of the parameters. Model 4 is estimated on median prices by individual periods, again discarding the first three periods of each market (Models 3 and 5 will be discussed in the price discrimination section, below). The underlying data generating process for Models 3 to 5 is assumed to be $P_{it}=\alpha+\beta' x_{it}+u_i+e_{it}$, where P_{it} is the price observation for session i, period t, x_{it} is the corresponding vector of observations on the regressors , (α,β') is a vector of coefficients, u_i is a randomly distributed session specific effect and e_{it} is a potentially autocorrelated error term, i.e. $e_{it}=\rho_i e_{i,t-1}+\epsilon_{it}$ with the ϵ_{it} distributed identically and independently both of each other and of the subject specific term u_i.

All estimates were made using a GEE technique as described by Liang and Zeger [14] and include a Huber/White sandwich error adjustment similar to that discussed in White [24]. This process uses the

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[12] We used the Huber/White sandwich error method from White [24] as implemented by the Stata command `xtreg` in StataCorp [21].

residuals from the initial regression to generate consistent standard errors even if the correlations within groups are not as hypothesized or if errors are heteroscedastic (see StataCorp [21] for details).

The larger data set permits controls for interactions and random session effects. Once again the equation is estimated using robust techniques correcting for both autocorrelation and heteroscedasticity. The results are essentially the same as for the simpler model. Model 4 has the advantage of allowing the effect of market structure to vary across the three markets of each session. The point estimates of the market effect (the difference between the predicted competitive and predicted market power price) are +12.9, + 11.6, and +10.0 cents for monopoly in Markets 1, 2 and 3 respectively and -24.9 , -15.4, and -18.0 cents for monopsony.[13] The differences among these effects are not significant, although it is interesting that the point estimates show no marked decline in the market structure effects between Markets 2 and 3.

4.2. Coupon Sales and Efficiency

We define net purchases as the difference between the number of coupons bought and sold by the agents who are predicted to be buyers (Agents 1 to 5). Since there is no coupon banking, this is also the number of coupons that the buyers redeemed.[14] Table VI reports net purchases cross-tabulated by treatment and market. There is some evidence that net purchases were restricted in our market power environments, however the extent of restriction is much less than the benchmark single-price monopoly or monopsony restrictions. Analysis of variance retains the null hypothesis that a three-way treatment classification has no effect on net purchases. If we combine the monopoly and monopsony categories, however, we can

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[13] Computed as 12.944, 12.944 - 1.318, and 12.944 - 2.916 for monopoly Markets 1, 2 and 3 respectively and in similar fashion for monopsony markets.

[14] Detailed examination of the data reveals an anomaly. In exactly one of the 118 periods we recorded the appearance of phantom coupons. In that period alone the software appears to have permitted two subjects to sell more coupons than they owned, so that their net purchases were negative. We have excluded this period from the following tabulations.

weakly reject the null of no effect of market power (F-test, p = 0.0709) while the null of no market sequence effect is maintained (F-test, p = 0.7118). Note that these are two-tailed tests.[15]

The relatively small coupon sales restriction suggests that we will not find that efficiency is significantly affected by market power. This is confirmed in Figure 2, which presents efficiency by treatment (market structure) and market order. On average our markets were quite efficient, achieving 91 percent of available gains from trade, with competitive, monopoly, and monopsony markets averaging efficiencies of 91, 92, and 89 percent respectively. One quarter of the individual markets (the two monopsony Markets 1, one monopsony Market 3, one monopoly Market 2, one competitive Market 1, and one competitive Market 3) exhibit substantially lower efficiencies (between 83 and 85 percent). The null hypothesis of no treatment (market structure) or market order effects is easily retained, however (F-tests, p = 0.5250 and p = 0.2737 respectively).

4.3. Speculation

Participants in these sessions are not restricted to the role of buyer or seller. Within any one period, participants may attempt to earn trading profits by buying and reselling coupons (short sales were not permitted). This feature permits the number of transactions in a period to exceed the net purchases. Table VII shows the mean number of transactions per period by treatment and market sequence. On average more than 11 coupons are traded each period in competitive markets, but only 7 net purchases are made (see Table VI). Nearly 38 percent of transactions are speculative.[16] Approximately 26 percent of the transactions in monopoly markets are speculative while fewer than 5 percent of monopsony market trades were speculative. This substantial difference between market structures is significant (F-test, p = 0.0484).

The large number of trades which took place in the competitive markets may have contributed to the

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[15] In light of the robust results obtained from the analysis of variance in prices, we did not conduct more elaborate regression analyses of the quantity and efficiency data.

[16] Computed as (11.40 - 7.07)/11.40 = 0.3798

relatively low efficiency (91 percent) in these markets as compared to competitive markets in which participants act as either buyers or sellers (for a summary of double-auction results see Davis and Holt [6, p. 136]. Speculative purchases in the markets with traders introduce sufficient noise that even the double auction is unable to discipline trading sufficiently to guarantee that all of the gains from trade are realized.

4.4. Profits

Although coupon sales were not greatly restricted by the exercise of market power, the distribution of profit certainly was. Table VIII reports profits by role, treatment and market. These profits include the fixed net revenues paid to inactive traders. The observed profits should be read in conjunction with the benchmarks of Table III. Consider the buyers. There is substantial variation among the observations. Nevertheless, in competitive markets they earned an average of 500 cents per period, exactly the benchmark profit. In monopoly markets their profits fell to 364, slightly above the benchmark of 344. In monopsony markets their profits rose to 601, somewhat below the benchmark of 604. Sellers' mean profits were 458 cents in competition (below the benchmark of 500), 602 under monopoly (barely above the benchmark of 601), and 350 under monopsony (slightly above the benchmark of 341). The treatment effect is statistically significant (one-way ANOVA, $p = 0.0000$, both for buyers and for sellers). We conclude that market structure has affected the distribution of profits in much the same manner as predicted by single price monopoly theory.

4.5. Price Discrimination

The fact that market power significantly affects prices and the distribution of profits but not efficiency suggests that agents with market power are able to practice systematic price discrimination. Visual inspection of the price data confirms this impression. For example, Figure 3 displays the contract prices by period as they were generated in the first monopoly market of the first SCS session (left side of figure) and the first monopsony market of the first BCB session (right side of figure). In the first market there is a single seller. Contracts are formed initially at prices above 113 cents and fall throughout each period, usually ending close to or in the competitive equilibrium price band. This pattern, which one would expect from a price-discriminating monopolist, does not decay across the 10 periods of the market.

A similar pattern is observed in the monopsony market (Figure 3, right hand side). In all periods prices begin low and then rise. Initial prices are first formed at below the single-price monopoly line at 61 cents and then rise towards the competitive price. Note that *opening* contract prices do not converge into the competitive equilibrium price band and are below the benchmark monopsony price.

These patterns in the period-by-period data are confirmed by regression analysis. Model 3 of Table V reports a panel regression on the opening prices of each period estimated using robust panel methods. (Once again, periods 1 - 3 of each market were dropped). The point estimate for competitive opening prices in Market 1 is 84.47 cents, almost at the competitive level. There is a strong influence of market order. The point estimates for the effect of monopoly on opening prices are +41.12, +26.55, and +24.16 cents for Markets 1, 2 and 3 respectively.[17] For monopsony they are -32.79, -21.32 and -23.86 cents.[18] Interaction effects are jointly significant. These estimates indicate that monopolists and monopsonists were most successful in exercising market power in opening prices during Market 1, but that there was little erosion in their ability to manipulate opening prices in Market 3 compared to Market 2. On the other hand, closing prices in all markets were very much closer to competitive levels. Model 5 of Table V reports a period-by-period regression on closing prices.[19] This suggests that closing prices in all market structures were essentially competitive. Note that the constant term (87.24) is within the competitive band and that we retain the nulls of no market structure effects and no interaction effects. This pattern of market power in opening and median prices coupled with competitive closing prices is consistent with successful price

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[17] Computed as 41.118, 41.118 - 15.566, and 41.118 - 16.963 respectively.

[18] Computed as -32.788, -32.788 + 11.462, and -32.788 + 8.930 respectively.

[19] This regression was run with fixed effects rather than random effects because a Hausmann [11] test rejected the hypothesis of independence between fixed effects and the remaining regressors.

discrimination.

4.6. Price Convergence Patterns

Our results suggest that the monopoly and monopsony subjects were able to manipulate prices to their advantage while participating in a double-auction market. Examination of the period-by-period median prices (see Figure 4) suggests that this effect does not disappear over the lifetime of each market. In an attempt to confirm this impression, we estimate the asymptotic median price for each market and test for treatment and market effects using a procedure similar to that of Noussair, Plott and Riezman [18]. We also estimate the asymptotic closing price for each market in order to evaluate the conjecture attributed to Porter [20] that price discrimination may arise in double-auction markets with market power.

We estimated the model

$$y_{it} = \sum_{i=1}^{3} (\beta_{i1} D_i (\frac{1}{t}) + \beta_{i2} D_i (\frac{t-1}{t})) + u_{it}, \; t \in \{1..10\}$$

where i is market number within session, t is period number within market and y_{it} is either median price or closing price for the period. $\boldsymbol{D_i}$ is a dummy for market $\boldsymbol{i}$. Interdependence of the observations was controlled by using the Newey-West [16] procedure to estimate the covariance matrix when heteroscedasticity or autocorrelation were indicated in the results of the original specification. Results of these regressions by session and market are presented in Tables IX and X. The mean asymptotic median and closing normalized prices by treatment and market (based on the estimated coefficients of $\beta_{i2}, \; i \in (1,2,3)$ in Tables IX and X) are presented in Table XI.

The results indicate that prices in monopoly and monopsony markets are not converging to competitive levels. Median prices in competitive markets converge on average to 87.8, within the competitive equilibrium band. Median prices in monopoly markets converge on average to 99.4, well above the competitive range. Median prices in monopsony markets converge on average to 68.2, well below the competitive range. The effect of treatment is strongly significant (p = 0.0000), while neither market sequence nor its interaction with treatment is significant (p = 0.2057 and p = 0.3704 respectively). The asymptotic median prices are broadly in line with the observed median prices (Table 4), thus showing that there is no tendency for median prices to converge to competitive levels as experience is gained. Averaged over all markets, asymptotic closing prices for competition lie within the equilibrium band. Similarly, asymptotic closing prices lie slightly below the competitive equilibrium band in the case of monopoly and substantially below the competitive equilibrium band in the case of monopsony. The main effect of treatment is significant (p = 0.0438) and the main effect of market sequence is weakly significant (p = 0.0823). There are no interaction effects. However, the sustained spread between median and closing prices suggests that agents with market power were systematically able to practice price discrimination.

5. DISCUSSION AND CONCLUSIONS

Our results clearly establish that both monopoly and monopsony subjects were able to manipulate prices to their advantage despite any limitations placed on them by the double-auction institution. This is not a transient effect which is eliminated with experience. We confirmed this by estimating the asymptotic median price for each market and testing for treatment and market effects.

The insignificant effect of market structure on efficiency and the relatively small constraint on net purchases, together with the observed price patterns, strongly suggests that efficiency losses were mitigated by price discrimination. As a result, subjects with market power were able to increase their share of the profits substantially (relative to the competitive environments) without greatly harming efficiency. The sustained spread between median and closing prices in the convergence analysis suggests that subjects with market power were systematically able to practice price discrimination.

Our experiment differed from Brown-Kruse *et al*. [3], Smith [22], and Smith and Williams [23] because our subjects could trade on both sides of the market. It differed from Ledyard and Szakaly-Moore [13] because it considered both monopsony and monopoly power. It differed from all previous research in the area because it included a competitive baseline against which the effect of market power could be measured, and because it included more monopoly and monopsony markets than any of the others.

Our results generally confirm the findings of Brown-Kruse *et al*. [3], Godby [7, 8, 9], and Ledyard and Szakaly-Moore [13], all of which present evidence that double auctions provide an ineffective constraint on market power. Unlike Godby [7, 8, 9], however, we find very little evidence of asymmetry between monopolists and monopsonists. Our results exhibit a stronger effect of market power in double auctions than was observed in most previous work. Table XII compares the price results across our experiment and five predecessors. To allow for the possibility of convergence to competitive equilibrium in a session we examine only the mean prices in the last periods reported (we shift from median prices here because the data from other experiments are described this way). In the present experiment, monopolists achieved 55 percent of the potential price increase while our monopsonists achieved 65 percent of the potential price declines. The monopolists were more successful than those in previous experiments (particularly those of Godby's, for whom the introduction of agents who could work both sides of the market led to a reduction in their ability to exert market power). The monopsonists were somewhat less successful in comparison. Particularly noteworthy, however, is the success of the monopolists, which suggests that Godby's results may be anomalous.

Our finding that price discrimination can persist in a double auction when all prices are public information challenges the hypothesis, suggested by Smith [22], that buyers' resistance to high prices is increased once the monopolist reveals himself prepared to sell at lower prices. A possible explanation of this difference may lie in the nature of our markets. Unlike those in Smith's experiments, our markets allowed speculative activity which, combined with the changing market "fundamentals" associated with within session treatment changes, could have created an environment in which it was easier for price discrimination to persist. Because naturally-occurring emissions markets would also be characterised by speculative activity and changing market conditions, our results suggest that market-power pricing and price discrimination may be serious problems in the field.

Our work has somewhat conflicting implications for emissions trading policy. On the one hand, it suggests that double-auction markets for emissions permits can be quite efficient, even when the buying or selling side is highly concentrated. On the other hand, it suggests that agents with market power may be able to use it to capture substantially increased shares of the gains from emissions trading. This may pose a problem in the context of international Greenhouse Gas trading if some countries directly trade their assigned amounts rather than delegating them to domestic entities. This may make negotiations of international trading arrangements more difficult. The problem of market power may be even greater in affecting the political feasibility of regional emissions trading markets in which there are likely to be single buyers.

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Table I

Basic Parameters For Competitive and Market Power Environments

	Trader Numbers (Potential Net Buyers)							Trader Numbers (Potential Net Sellers)						
	Monopsony		Competition and Monopoly					Competition and Monopsony					Monopoly	
	1	2 - 5	1	2	3	4	5	6	7	8	9	10	6 - 9	10
Net Sales Revenue	-156	100	34	44	52	56	58	-109	-87	-74	-74	-74	100	-818
Coupon Allocation	0	0	0	0	0	0	0	2	2	2	2	2	0	10
Redemption Value														
Coupon 1	153	0	153	143	133	123	113	122	100	85	77	70	0	122
Coupon 2	143	0	80	84	89	95	103	52	52	52	52	61	0	100
Coupon 3	133	0	0	0	0	0	0	0	0	0	0	0	0	85
Coupon 4	123	0	0	0	0	0	0	0	0	0	0	0	0	77
Coupon 5	113	0	0	0	0	0	0	0	0	0	0	0	0	70
Coupon 6	103	0	0	0	0	0	0	0	0	0	0	0	0	61
Coupon 7	95	0	0	0	0	0	0	0	0	0	0	0	0	52
Coupon 8	89	0	0	0	0	0	0	0	0	0	0	0	0	52
Coupon 9	84	0	0	0	0	0	0	0	0	0	0	0	0	52
Coupon 10	80	0	0	0	0	0	0	0	0	0	0	0	0	52
Profit in Efficient Allocation[a]	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[a] Profit in efficient allocation includes both net trading revenue and the value of coupons redeemed.

Table II
Experimental Design

Treatment		Market			
Replications	Symbol	0	1	2	3
2	CSC	Practice	Competition	Monopoly	Competition
2	SCS	Practice	Monopoly	Competition	Monopoly
2	CBC	Practice	Competition	Monopsony	Competition
2	BCB	Practice	Monopsony	Competition	Monopsony

Table III

Benchmarks

Benchmark	Net Purchases	Price	Profit			Gains from trade	Efficiency
			Buyers	Sellers	Market		
No Trade	0		244	305	549		
Competition	8	85 - 89	500	500	1000	451	100.00%
Monopoly	5	113	344	601	945	396	87.80%
Monopsony	5	61	604	341	945	396	87.80%

Table IV

Mean of the Median per Period Normalized Prices by Session and Market and by Treatment and Market

(Number of Observations in Parentheses)[a]

	Market			
Treatment	1	2	3	Total
Competition	83.51 (4)	89.11 (4)	84.21 (4)	85.61 (12)
Monopoly	100.05 (2)	101.80 (2)	94.83 (2)	98.89 (6)
Monopsony	53.40 (2)	78.42 (2)	66.03 (2)	65.95 (6)
Total	80.12 (8)	89.61 (8)	82.31 (8)	84.02 (24)

[a] Data are median prices per period averaged over all periods of each market.

Table V

Regression Estimates of Alternative Price Models (*p*-values are in parentheses)

	Regression Models				
	Dependent Variable ($P_{i\bullet}$)		Dependent Variable (P_{it})		
Estimated Coefficients[a]	**Model (1)** Mean of Medians (all periods)	**Model (2)** Mean of Medians (after period 3)	**Model (3)** Opening Period Price	**Model (4)** Median Period Price	**Model (5)** Closing Period Price[b]
Constant (a)	**81.677** **(0.000)**	**84.729** **(0.000)**	**84.476** **(0.000)**	**85.277** **(0.000)**	**87.243** **(0.000)**
Monop (b_1)	**13.204** **(0.010)**	**12.489** **(0.002)**	**41.118** **(0.000)**	**12.944** **(0.001)**	-4.769 (0.126)
Monops (b_2)	**-19.663** **(0.000)**	**-20.296** **(0.000)**	**-32.788** **(0.000)**	**-24.864** **(0.000)**	-6.868 (0.227)
Mkt2 (b_3)	9.550 (0.058)	6.141 (0.110)	8.579 (0.316)	5.085 (0.192)	**7.701** **(0.013)**
Mkt3 (b_4)	2.256 (0.568)	-0.259 (0.934)	-2.853 (0.655)	-1.429 (0.653)	**-6.663** **(0.037)**
Mpmkt2 (b_5)	N.A.	N.A.	-15.566 (0.174)	-1.318 (0.889)	N.A.
Mpmkt3 (b_6)	N.A.	N.A.	**-16.963** **(0.033)**	-2.916 (0.720)	**12.727** **(0.022)**
Msmkt2 (b_7)	N.A.	N.A.	11.462 (0.228)	9.495 (0.099)	-4.347 (0.614)
Msmkt3 (b_8)	N.A.	N.A.	8.930 (0.162)	6.873 (0.203)	8.646 (0.119)
Adjusted R^2	0.671	0.759	N.A.[c]	N.A.[c]	N.A[c]
F-statistic of Regression[d]	**10.50** **(0.000)**	**18.09** **(0.000)**	N.A.	N.A.	N.A.
Structure Test H_0: $b_1=b_2=0$	$\boldsymbol{p = 0.000}$	$\boldsymbol{p = 0.000}$	$\boldsymbol{p = 0.000}$	$\boldsymbol{p = 0.000}$	$p = 0.139$
Order Test H_0: $b_3=b_4=0$	$p = 0.133$	$p = 0.171$	$p = 0.272$	$p = 0.322$	$\boldsymbol{p = 0.001}$
Interaction Test[e] H_0: $b_5=b_6=b_7=b_8=0$	N.A.	N.A.	$\boldsymbol{p = 0.000}$	$p = 0.366$	$p = 0.109$
Monopoly Test H_0:	$b_1= - (b_3+b_4)/3$ $\boldsymbol{p = 0.001}$	$b_1= - (b_3+b_4)/3$ $\boldsymbol{p = 0.001}$	$b_1 = - (b_3+b_4)/3 - (b_5+b_6)/9$ $\boldsymbol{p = 0.000}$	$b_1 = - (b_3+b_4)/3 - (b_5+b_6)/9$ $\boldsymbol{p = 0.000}$	N.A.[f]
Monopsony Test H_0:	$b_1= - (b_3+b_4)/3$ $\boldsymbol{p = 0.001}$	$b_1= - (b_3+b_4)/3$ $\boldsymbol{p = 0.000}$	$b_1 = - (b_3+b_4)/3 - (b_7+b_8)/9$ $\boldsymbol{p = 0.001}$	$b_1 = - (b_3+b_4)/3 - (b_7+b_8)/9$ $\boldsymbol{p = 0.000}$	N.A.[f]

[a] All estimates were made using a GEE technique and include a Huber/White sandwich standard error adjustment. Models (1) - (4) include a random session effect. See note 2 for Model (5).

[b] The Model (5) regression on closing prices was estimated using a fixed effects model with separate coefficients estimated for each session. For clarity, these are not reported. The variable Mpmkt2 was dropped from the Model (5) regression to avoid perfect collinearity among the regressors.

[c] An R^2 computation is not appropriate for GEE estimation methods.

[d] For regressions (1) and (2), $F(4, 19)$ is reported. N.A. is reported in cells for regressions (3) - (5) as the test is not applicable to GEE methods.

[e] For Model (5), note that variable b_5 was dropped from this regression as it would induce perfect collinearity between the interaction and seven Session dummies in this specification.

[f] This test could not be performed due to the incomplete set of interaction dummies (see Note 5).

Table VI

Mean Net Purchases of Coupons per Period, by Treatment and Market

(Number of Observations in Parentheses)[a]

	Market			
Treatment	1	2	3	Total
Competition	7.05 (4)	6.68 (4)	7.48 (4)	7.07 (12)
Monopoly	6.75 (2)	6.25 (2)	7.15 (2)	6.72 (6)
Monopsony	5.45 (2)	7.21 (2)	5.61 (2)	6.09 (6)
Market Power (Monopoly and Monopsony combined)	6.10 (4)	6.73 (4)	6.38 (4)	6.40 (12)
Total	6.58 (8)	6.70 (8)	6.93 (8)	6.73 (24)

[a] Net purchases are the differences between coupons purchased and coupons sold by the agents who are predicted to be buyers in the benchmark equilibria by treatment and market. Data are the means over the observed number of periods, excluding Period 6 of Market 3, Session 3, during which a computer error allowed excessive coupon use.

Table VII

Mean Purchases of Coupons per Period, by Treatment and Market

(Number of Observations in Parentheses)[a]

	Market			
Treatment	1	2	3	Total
Competition	13.43 (4)	9.28 (4)	11.50 (4)	11.40 (12)
Monopoly	7.75 (2)	10.95 (2)	8.55 (2)	9.08 (6)
Monopsony	5.80 (2)	7.55 (2)	5.80 (2)	6.38 (6)
Total	10.10 (8)	9.26 (8)	9.34 (8)	9.57 (24)

[a] Data are the means over the observed number of periods.

Table VIII

Mean Profit per Period by Treatment, Market and Role (Number of Observations in Parentheses)[a]

	Market			
Role and Treatment	1	2	3	Total
Buyers				
Competition	507 (4)	475 (4)	518 (4)	500 (12)
Monopoly	334 (2)	354 (2)	403 (2)	364 (6)
Monopsony	638 (2)	554 (2)	613 (2)	601 (6)
Sub-Total	497 (8)	464 (8)	513 (8)	491 (24)
Sellers				
Competition	441 (4)	475 (4)	450 (4)	458 (12)
Monopoly	637 (2)	598 (2)	572 (2)	602 (6)
Monopsony	286 (2)	430 (2)	333 (2)	350 (6)
Sub-Total	451 (8)	499 (8)	451 (8)	467 (24)
Total: Buyers plus Sellers	948	963	964	958

[a] Data are the mean profit per period for all five buyers or sellers respectively, including fixed net revenues. Period 6 of Market 3 in Session 3 was excluded. Data for Market 2 of Session 4 (a competitive market) are the means of the 8 observed periods.

Table IX

Convergence Patterns of Median Normalized Prices by Period

	Estimated Series Asymptote			Confidence Interval (95%)		Prediction			
Session # and Market Structure	β_{2i}	**Median Price**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Market Power**	**Comp.**	**Adj. R^2**	**No. Obs.**
1C	β_{21}	94.79	1.703	91.27	98.31	N.A.	85-89	0.928	30
1S	β_{22}	105.71	1.703	102.19	109.23	113	85-89		
1C	β_{23}	82.69	1.703	79.17	86.20	N.A.	85-89		
2S	β_{21}	103.09	2.097[a]	98.77	107.42	113	85-89	0728	30
2C	β_{22}	93.58	0.444[a]	92.67	94.50	N.A	85-89		
2S	β_{23}	91.51	1.476[a]	88.46	94.56	113	85-89		
3C	β_{21}	86.93	1.710	83.40	90.45	N.A	85-89	0.610	30
3B	β_{22}	71.78	1.710	68.25	75.31	61	85-89		
3C	β_{23}	85.16	1.710	81.63	85.16	N.A.	85-89		
4B	β_{21}	63.62	3.028	57.34	69.90	61	85-89	0.857	28
4C	β_{22}	82.38	3.597	74.92	89.84	N.A.	85-89		
4B	β_{23}	67.94	3.028	61.66	74.22	61	85-89		
5C	β_{21}	88.95	2.006	84.81	93.09	N.A.	85-89	0.735	30
5S	β_{22}	92.45	2.006	88.31	96.59	113	85-89		
5C	β_{23}	77.34	2.006	73.20	81.48	N.A.	85-89		
6S	β_{21}	103.50	2.396	98.56	108.45	113	85-89	0.733	30
6C	β_{22}	100.16	2.396	95.21	105.11	N.A	85-89		
6S	β_{23}	99.84	2.396	94.89	104.79	113	85-89		
7C	β_{21}	85.70	1.903	81.77	89.63	N.A	85-89	0.784	30
7B	β_{22}	78.53	1.903	74.60	82.46	61	85-89		
7C	β_{23}	92.19	1.903	88.26	96.12	N.A.	85-89		
8B	β_{21}	61.65	1.435	58.69	64.61	61	85-89	0.924	30
8C	β_{22}	84.05	1.435	81.09	87.01	N.A.	85-89		
8B	β_{23}	65.58	1.435	62.62	68.54	61	85-89		

[a] For this session the Newey-West [16] procedure is used to estimate the covariance matrix because heteroscedasticity or autocorrelation were indicated in the results of the original specification.

Table X

Convergence Patterns of Closing Normalized Prices by Period

	Estimated Series Asymptote			Confidence Interval (95%)		Prediction			
Session # and Market Structure	β_{2i}	**Closing Price**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Market Power**	**Comp.**	**Adj. R^2**	**No. Obs.**
1C	β_{21}	99.15	11.65	75.10	123.20	N.A.	85-89	0.153	30
1S	β_{22}	87.58	11.65	63.53	111.63	113	85-89		
1C	β_{23}	71.23	11.65	47.18	95.29	N.A.	85-89		
2S	β_{21}	71.26	3.552[a]	63.92	78.59	113	85-89	0.514	30
2C	β_{22}	88.79	3.421[a]	81.73	95.85	N.A	85-89		
2S	β_{23}	84.32	1.371[a]	81.49	87.15	113	85-89		
3C	β_{21}	86.32	2.305	81.56	91.08	N.A	85-89	0.221	30
3B	β_{22}	80.99	2.305	76.23	85.75	61	85-89		
3C	β_{23}	83.21	2.305	78.45	87.97	N.A.	85-89		
4B	β_{21}	76.59	3.083	70.19	82.98	61	85-89	0.514	28
4C	β_{22}	85.41	3.662	77.82	93.01	N.A.	85-89		
4B	β_{23}	80.69	3.083	74.29	87.08	61	85-89		
5C	β_{21}	90.82	3.226[a]	84.16	97.48	N.A.	85-89	0.132	30
5S	β_{22}	92.40	2.269[a]	87.72	97.08	113	85-89		
5C	β_{23}	76.22	2.709[a]	70.63	81.81	N.A.	85-89		
6S	β_{21}	84.66	4.399	75.58	93.74	113	85-89	0.228	30
6C	β_{22}	98.32	4.399	89.24	107.40	N.A	85-89		
6S	β_{23}	89.44	4.399	80.36	98.52	113	85-89		
7C	β_{21}	81.95	4.217	73.25	90.66	N.A	85-89	0.181	30
7B	β_{22}	85.03	4.217	76.33	93.74	61	85-89		
7C	β_{23}	87.60	4.217	78.90	96.30	N.A.	85-89		
8B	β_{21}	74.08	2.895	68.10	80.05	61	85-89	0.725	30
8C	β_{22}	88.4	2.895	82.47	94.42	N.A.	85-89		
8B	β_{23}	68.72	2.895	62.74	74.70	61	85-89		

[a] For this session the Newey-West [16] procedure is used to estimate the covariance matrix because heteroscedasticity or autocorrelation were indicated in the results of the original specification..

Table XI

Asymptotic Median and Closing Normalized Prices by Treatment and Market

(number of observations in parentheses)

	Asymptotic Median Prices				Asymptotic Closing Prices			
	Market				Market			
Treatment	1	2	3	Total	1	2	3	Total
Competition	89.09 (4)	90.04 (4)	84.35 (4)	87.83 (12)	89.56 (4)	90.24 (4)	79.57 (4)	86.46 (12)
Monopoly	103.30 (2)	99.08 (2)	95.67 (2)	99.35 (6)	77.96 (2)	89.99 (2)	86.88 (2)	84.94 (6)
Monopsony	62.63 (2)	75.15 (2)	66.76 (2)	68.18 (6)	75.33 (2)	83.01 (2)	74.71 (2)	77.68 (6)
Total	86.02 (8)	88.58 (8)	85.80 (8)	85.79 (24)	83.10 (8)	88.37 (8)	80.18 (8)	83.88 (24)

Table XII

Mean Percentage Change in Mean Contract Price from Competitive Benchmark to Market Power Benchmark in the Last Period, by Experiment and Treatment (Number of Sessions in Parentheses)[a]

	Smith	Smith and Williams	Ledyard and Szakaly-Moore	Brown Kruse et al.	Godby	Present Experiment
Monopoly	25 (3)	7 (5)	77 (3)	40 (3)	-60 (3)	55 (6)
Monosony				166 (3)	147 (3)	65 (6)

[a] Sources for this table are Smith [22], Smith and Williams [23], Ledyard and Szakaly-Moore [13], Brown-Kruse, Elliott and Godby [3] and Godby [7] .

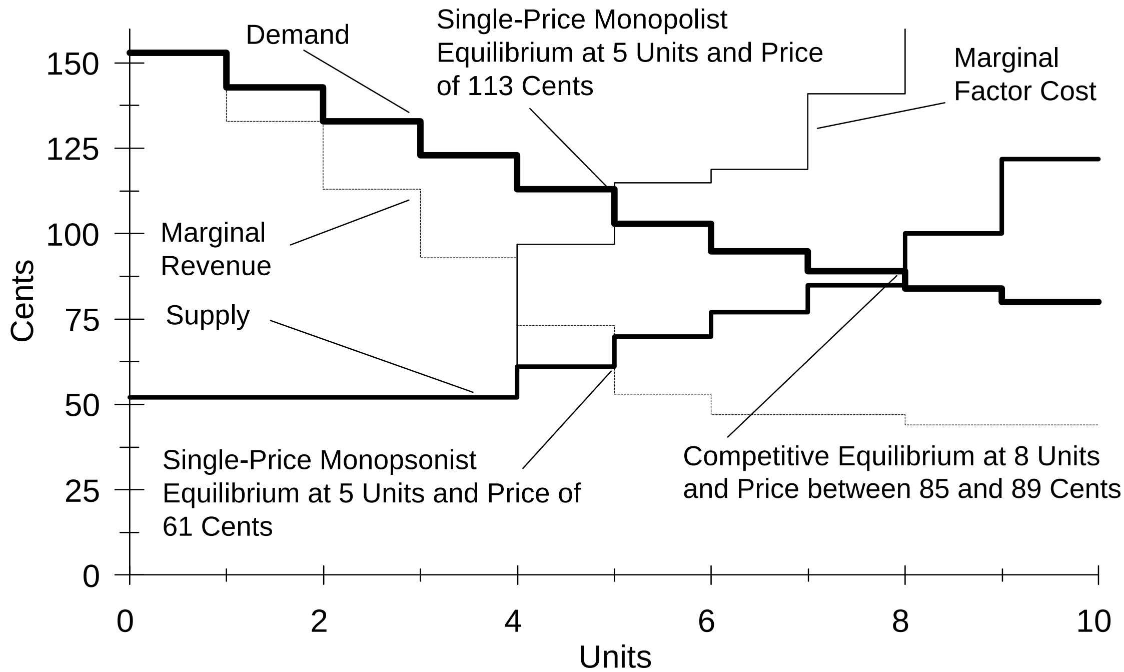

FIG. 1. Supply, Demand, Marginal Revenue, and Marginal Factor Cost Schedules

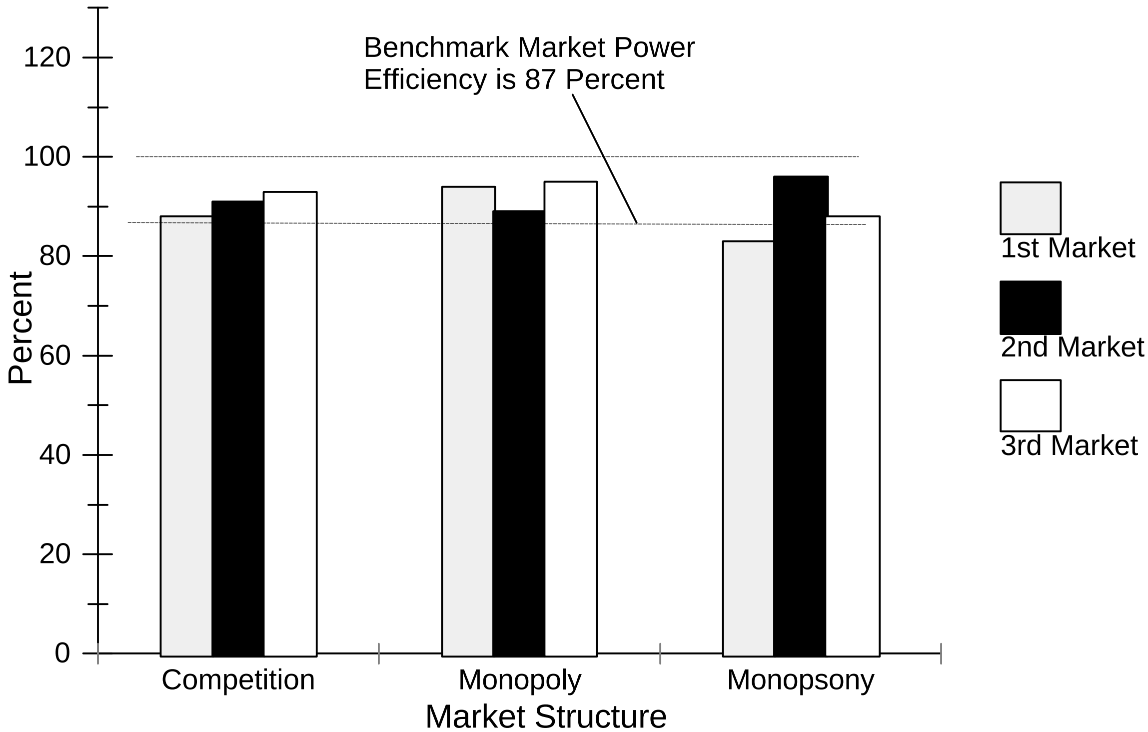

FIG. 2. Mean Market Efficiency by Market Structure and Market Order

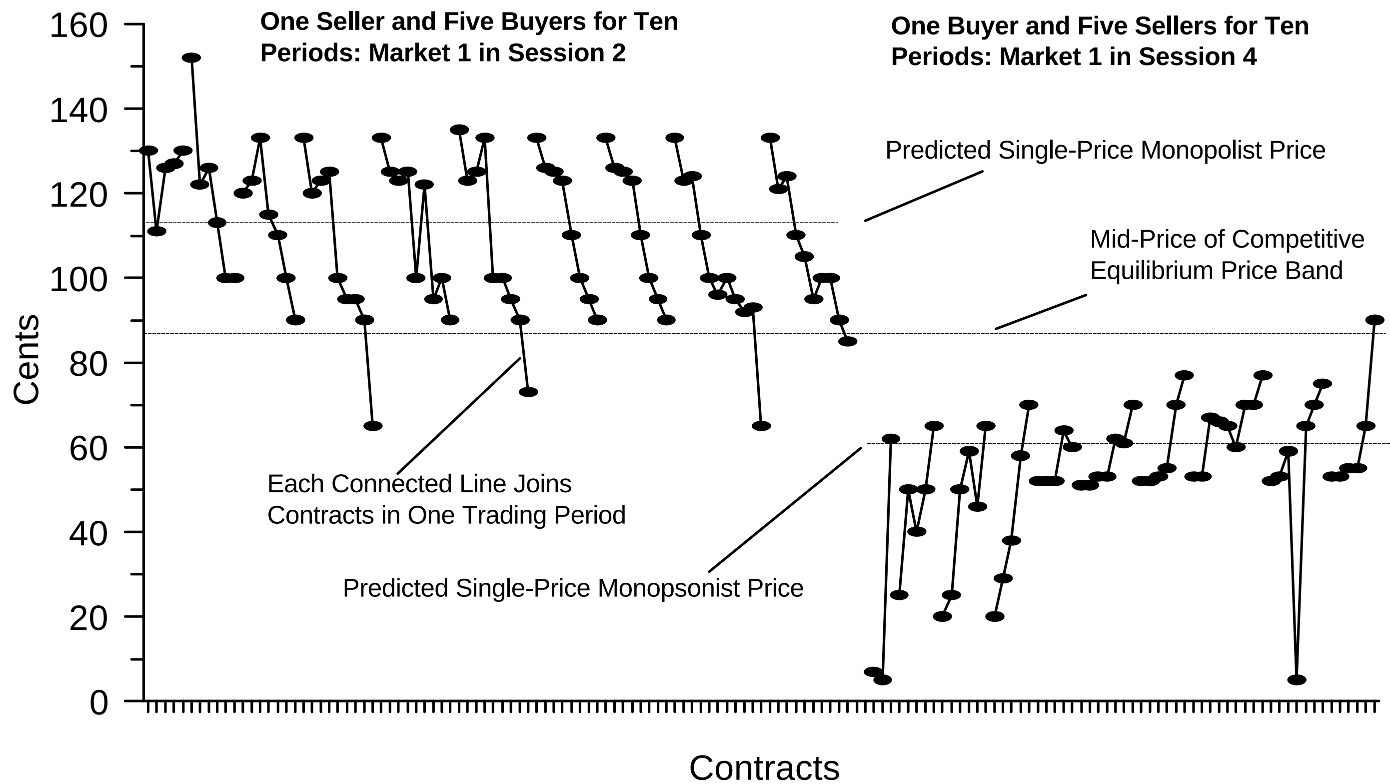

FIG. 3. Actual Contract Prices for Market 1 in Session 2 (Single Seller) and Market 1 in Session 4 (Single Buyer)

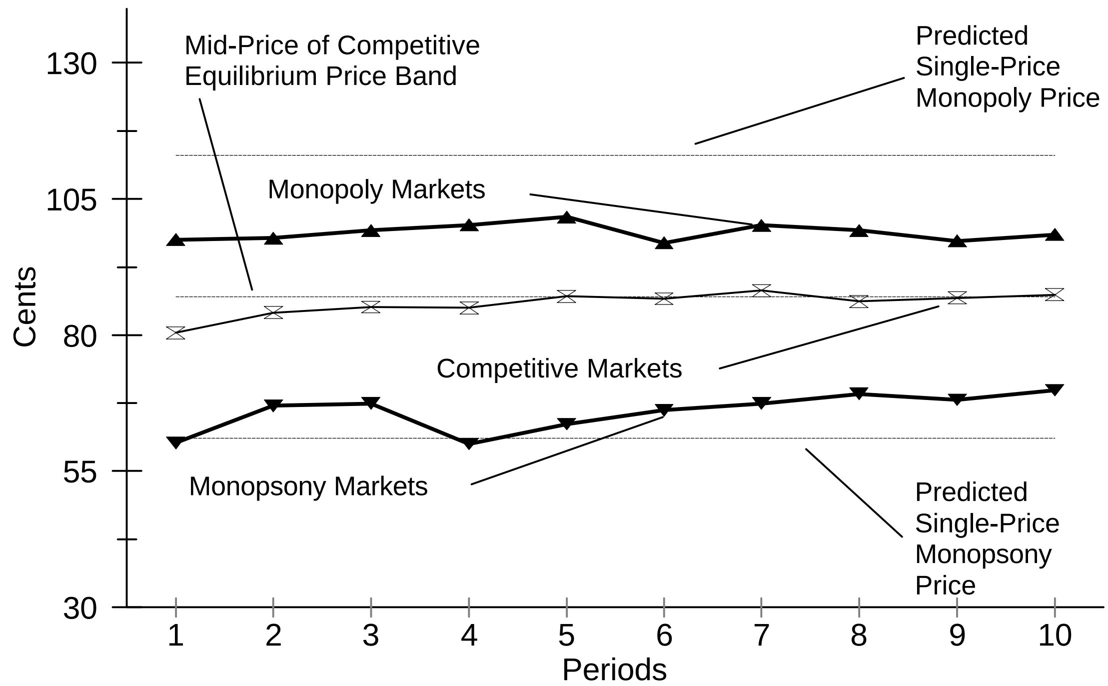

FIG. 4. Mean of Median Contract Prices by Period across 12 Competitive, 6 Monopoly and 6 Monopsony Markets